THERMAL SPRAY GRIT ROLLER

Background of the Invention

This invention relates generally to paper feed mechanisms for printers or the like. More particularly, the present invention relates to a pressure contact roller for use in a feed mechanism for advancing a sheet of paper to a recording position in a printer.

In early computer printers, and the like, the paper, or other print record medium, was incrementally stepped along a paper path. In such a printer, one requirement was that the stepping be precisely controlled to maintain proper registration of the lines of print on the paper. Generally, this was accomplished by providing the paper with a series of equally spaced holes along the edges thereof and to provide the printer with a roller having sprocket wheels with circumferentially spaced pins on the periphery thereof. These sprocket wheels engaged the holes of the paper to feed the paper while maintaining the required registration. To allow continuous printing of multiple page documents, the paper was provided as continuous fan-folded "ribbon" of paper. The paper ribbon commonly had longitudinally spaced lateral lines of perforations to facilitate separating the ribbon into individual paper sheets. In addition, the paper ribbon often had longitudinally extending lines of perforations at the margins of the ribbon to facilitate removal of the side portions of paper having the holes. However, the paper edge left by using the perforations was rough compared to conventionally cut sheets of paper and paper that did not have indexing holes along each edge could not be used in these printers.

Friction feed rollers have substantially replaced sprocket wheels in more recent computer printers, and the like. Generally, the outer surface of the feed roller frictionally engage the paper and the feed roller is rotated by a paper feed motor to advance the sheet of paper to the print head. Pressure contact rollers are rotatably disposed near the feed rollers, and are held in pressure contact with outer surfaces of the corresponding feed

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rollers to cooperatively advance a sheet of paper disposed between the pressure contact rollers and the feed rollers.

The rollers are usually manufactured by forming a rod-like roller shaft by machining or molding, and then integrally forming a substantially cylindrical roller body made of an elastomer material over an outer circumference of the roller shaft. Because the recording surface of the sheet of paper contacts the outer surface of the roller body, the roller body is required to be made of an elastomer material that does not affect the recording surface.

Generally, the elastomer material used to produce conventional rollers has a relatively short lifetime and is rather sensitive to temperature variance. Temperature induced contraction or expansion of the roller body has a deleterious effect on the functional performance of the roller.

Summary of the Invention

Briefly stated, the invention in a preferred form is a thermal spray grit roller which includes a roller shaft having an outer periphery and a roller body connected to the outer periphery of the roller shaft. A grit layer comprising a multiple individual grit particles is deposited on the circumferential outer surface of the roller body by a thermal spray process.

The grit particles are each composed of an electrically conductive material or a ceramic material. The electrically conductive material may be aluminum, aluminum alloy, zinc, zinc alloy, copper, brass, nickel, titanium, carbon steel, stainless steel, chrome, iron, cobalt, molybdenum, chromium carbide, and tungsten carbide. The ceramic material may be aluminum oxide, chromium oxide, and zirconium oxide.

A method for manufacturing a thermal spray grit roller comprises the steps of collecting raw materials for use in the method, including at least one roller subassembly, having a roller body connected to a roller shaft, and the application material. The outer surface of each roller body is

degreased. Then, any portion of the roller body outer surface that will not be covered by the grit layer is masked. Finally, the grit layer is formed on the roller body outer surface with a thermal spray process.

The step of degreasing includes immersing the roller subassemblies in a tank containing trichloromethane for 20 to 30 seconds and then air drying the roller subassemblies for approximately 60 seconds.

The method may further comprise inspecting a representative sample of the rollers after forming the grit layer.

The step of inspecting the raw materials includes ensuring that the application material is the correct material, ensuring that the dimensions of the roller shaft and roller body conform to specification, and ensuring that the roller shaft and roller body conform to cosmetic requirements.

For roller bodies composed of metal, the method further comprises sandblasting the outer surface of the roller bodies, after the roller bodies are masked, to remove any oxidation. The sandblasting includes setting a sandblasting gun to 3 to 4.5 psi and blasting the roller body surface for 25 to 50 seconds with sand having a particle size of #80 to #200. More generally, the sandblasting includes blasting the roller body surface to produce a roughness average of 0.2 to 1.0 Ra. After sandblasting, the roller body surface is cleaned with an air brush.

The grit layer may be formed by installing electrodes or verifying that electrodes of the application material are installed in an arc spray machine, setting the arc spray machine output power, setting the arc spray machine compressed air pressure, setting or verifying the gap between the spray gun and the roller body surface, setting the spray gun feed rate, setting the rotational speed of the roller, and energizing the arc spray machine for a predetermined period of time, whereby the arc spray machine deposits a grit layer having the specified surface roughness and the specified thickness.

Alternatively, the grit layer may be formed by installing or verifying the installation of the application material and a bonding agent in a plasma spray machine, setting the plasma spray machine output power, setting the plasma spray machine gas pressure, setting or verifying the gap between the spray gun and the roller body surface, setting the spray gun feed rate, setting the rotational speed of the roller, and energizing the plasma spray machine for a predetermined period of time, whereby the plasma spray machine deposits a grit layer having the specified surface roughness and the specified thickness.

An initial grit layer of the application material to the roller body surface with an arc spray machine.

Brief Description of the Drawings

The present invention may be better understood and its numerous objects and advantages will become apparent to those skilled in the art by reference to the accompanying drawings in which:

Figure 1 is a perspective view of a first embodiment of a roller in accordance with the invention;

Figure 2 is an enlarged cross-sectional view taken along line 2-2 of Figure 1;

Figure 3 is an enlarged cross-sectional view of a second embodiment of a roller in accordance with the invention;

Figure 4 is a flow diagram of the thermal spray process for making a roller in accordance with the invention; and

Figure 5 is a plan view, enlarged 200 times, of the thermal spray grit surface produced by the process of Figure 4.

Detailed Description of the Preferred Embodiment

With reference to the drawings wherein like numerals represent like parts throughout the several figures, a roller having a thermal spray grit

surface in accordance with the present invention is generally designated by the numeral 10.

With reference to Figures 1 and 2, a first embodiment of the subject roller 10 has a columnar roller shaft 12 formed by molding or machining. The roller shaft 12 may be any material conventionally utilized in the construction of printer roller shafts. Over an outer periphery 14 of the roller shaft 12, a roller body 16 having a cylindrical circumferential outer surface 18 is formed integrally with the roller shaft 12 or fixedly mounted to the roller shaft 12, depending on the materials utilized to manufacture the roller shaft 12 and the roller body 16. The roller body 16 may be ceramic, a polymeric material or metal, for example stainless steel, copper or aluminum. The outer diameter of the roller body 16 is larger than the outer diameter of the roller shaft 12.

In a second embodiment (Figure 3), the subject roller 10' has a cylindrical roller shaft 12' formed by molding or machining and composed of any material conventionally utilized in the construction of such printer roller shafts. A cylindrical roller body 16' is coaxially, fixedly mounted to the roller shaft 12' by multiple spokes 20. Alternatively, the roller shaft 12', spokes 20 and roller body 16' may be formed integrally. Similar to roller body 16, the roller body 16' may be ceramic, a polymeric material or metal, for example stainless steel, copper or aluminum.

A layer of grit 22 is deposited on the outer surface 18, 18' of the roller body 16, 16' such that the outer surface 24 of the roller 10 has an optimal coefficient of friction for engaging a paper sheet being transported through the printer. As described below, the grit layer 22 is formed by depositing individual grit particles 26 by either an arc spray procedure or a plasma spray procedure. Initially, the grit particles 26 are deposited on the outer surface 18, 18' of the roller body 16, 16', and then subsequent grit particles 26 are deposited on the initial grit particles 26 to build the grit layer 22 to the desired thickness.

In the arc spray procedure 28, two wires are inserted into a torch and brought into contact with each other at the nozzle. The electrical load placed on the wires causes the tips of the wires to melt where they touch. A carrier gas such as air or nitrogen is used to strip the molten material off the wires as fine metal particles and to transport the molten particles to the workpiece. Since the electrodes must conduct electricity to form the arc, the metal wires forming the electrodes must be composed of an electrically conductive material. For example, aluminum, aluminum alloy, zinc, zinc alloy, copper, brass, nickel, titanium, carbon steel, stainless steel, or chrome. Preferably, the metal wires are composed of grade 316 stainless steel (SUS 316) which has high wear resistance (providing accurate paper feeding and minimizing compression set from the pinch rollers), has high corrosion resistance (preventing rust formation from ink aerosol and environmental humidity), and is highly conductive (facilitating discharge of static electricity).

In the plasma spray procedure 30, a compressed gas (e.g. argon, nitrogen, helium, or hydrogen) is passed through a torch. An electrical field in the torch creates an electrical arc that disassociates and ionizes the gases. Beyond the nozzle, the atomic components recombine, giving off a tremendous amount of heat. In fact, the plasma core temperatures are typically greater than 10,000°C, well above the melting temperature of any material. A powder including the application material and a bonding agent is injected into this flame, melted (forming a plasma), and accelerated to the workpiece. Since the application material is not required to conduct an electrical current, electrically non-conductive application materials may be used. For example, aluminum oxide, chromium oxide, and zirconium oxide. Alternatively, electrically conductive material may be used. For example, aluminum, aluminum alloy, iron, copper, cobalt, molybdenum, nickel, chromium carbide, and tungsten carbide.

The particle velocities for plasma are higher than for those of arc spraying and result in coatings that are typically denser and have a finer as-sprayed surface roughness. The tradeoff of increased density, however, is that the maximum coating thickness for a given material is usually reduced. As both metals and ceramics can be effectively sprayed with this technique, plasma spraying lends itself to automation and to reducing process steps.

A grit layer 22 produced by either the arc spray procedure 28 or the plasma spray procedure 30 is superior to conventional elastomeric roller bodies for a number of reasons. A metal or a metal alloy can be used in either procedure 28, 30 and a ceramic material may be used in the plasma spray procedure 30, providing great versatility. The use of a metal coating provides a roller 10, 10' that has close to zero compression set. The thickness of the grit layer 22 may be controlled very tightly, either spray procedure 28, 30 providing a tolerance of +/- 0.02 mm. The generation of the metal particles may be adjusted in the arc spray procedure 28, allowing the grit roughness to be controlled to provide ideal friction and traction. Although the metal particles are molten material, the overall arc spray procedure is performed in a relatively low temperature, preventing temperature related damage to the roller shaft 12 and roller body 16, 16'. Since the grit layer 22 may be electrically conductive, the roller 10, 10' is easily grounded, preventing static charge accumulation that attracts dust particles. For most printer uses, the advantages provided by an electrically conductive grit layer 22 militate against the use of an electrically non-conductive application material. The cost of rollers 10, 10' produced by the arc spray procedure 28 is low relative to the cost of rollers having a conventional rubber surface, for example ethylene propylene diene monomer (EPDM), or epoxy/PU grit coating.

With reference to Figure 4, the raw materials 32 used in the subject thermal spray process 34 includes a roller subassembly, comprising the

assembled/integrally manufactured roller shaft 12, 12' and roller body 16, 16', and the application material to be sprayed on the roller body 16, 16'. These raw materials are initially inspected 36 to ensure that the application material is the correct material, that the dimensions of the roller shaft 12, 12' and roller body 16, 16' conform to specification and cosmetic requirements.

The outer surface 18, 18' of the roller bodies 16, 16' of conforming roller subassemblies are then degreased 38 with a conventional degreasing agent. Any oil film remaining on surface 18, 18' will interfere with deposition of the initial grit particles 26 onto the roller body surface 18, 18', allowing the affected portions of the grit layer 22 to peel off during operation of the printer. Accordingly, care must be taken that the degreasing agent is properly applied and that the roller body surface 18, 18' is completely free of oil. Preferably the roller subassemblies are immersed in a degreasing tank containing trichloromethane for 20 to 30 seconds and then air dried for approximately 60 seconds.

After the entire outer surface 18, 18' of the roller body 16, 16' is degreased 38, those portions of the outer surface 18, 18' that will not be covered by the grit layer 22 are masked 40, preferably with polyurethane protector.

If the roller body 16, 16' is composed of metal, the outer surface 18, 18' will commonly have an oxidation layer. Since such an oxidation layer would interfere with the initial grit particles 26 adhering to the outer surface 18, 18', the outer surface 18, 18' is sandblasted 42 to remove any surface oxidation that may be present in the non-masked area. The particle size of the sand used in the blasting procedure 42 is dependent on the composition of the roller body 16, 16'. However, a particle size of #80 to #200 will generally be sufficient. Preferably, the sandblasting gun is set to 3 to 4.5 psi and the surface 18, 18' of the roller body 16, 16' is blasted for 25 to 50 seconds to produce a roughness average of 0.2 to 1.0 Ra.

Any sand dust remaining on the roller body surface 18, 18' after the sandblasting procedure 42 is removed by "sweeping" 44 the roller body surface 18, 18' with an air brush created by an air gun operated at 2 to 3 psi. Generally sweeping 44 the roller body surface 18, 18' for approximately 2 seconds is sufficient to remove the sand dust, that would otherwise create pin holes in the grit layer 22. After the sandblasting procedure 42 is completed, the sweeping procedure 44 is conducted and the spray procedure 28, 30 is begun as expeditiously as possible to prevent the formation of new oxides on the roller body surface 18, 18'.

With additional reference to Figure 6, the arc spray procedure 28 begins with determining 46 which application material will be used to form the grit layer 22 and either installing electrodes 48 of the proper material or verifying that electrodes of the proper material are already installed. The arc spray procedure 28 can be controlled to produce a specified grit layer thickness and a specified grit layer roughness. The rate at which the application material is deposited on the roller body surface 18, 18' determines the surface roughness of the grit layer 22, with the roughness increasing as the application material is deposited more quickly. The rate of application material deposition is controlled by the output power of the arc spray machine and/or the pressure of the compressed air used to transport the spray particles from the arc spray machine to the roller body surface 18, 18'. Therefore, the next steps in the arc spray procedure 28 require setting the arc spray machine output power 50 and the compressed air pressure 52. These steps 50, 52 may be performed simultaneously or serially.

With respect to the output power of the arc spray machine, the intensity of the electrical arc increases as the output power is increased. The greater the intensity of the electrical arc, the faster the application material of the electrodes is melted and ultimately deposited onto the roller body surface 18, 18'. The flow of compressed air through the arc spray

machine acts to cool the electrodes. Accordingly, increasing the pressure/flow rate reduces the rate at which the electrodes are melted for any given arc spray machine power level and reducing the pressure/flow rate increases the rate at which the electrodes are melted for any given arc spray machine power level. Preferably, the arc spray machine power is in the range of 25 to 35 volts and 50 to 300 amps and the compressed air pressure is in the range of 4 to 7 psi.

The thickness of the grit layer 22 is controlled by the feed speed of the spray gun. As the feed speed slows down, more grit particles 26 can be deposited onto the roller body surface 18, 18' to increase the thickness. The distance between the spray gun and the roller body surface 18, 18' and the rate at which the roller 10, 10′ is rotated as the application material must also be controlled. Therefore, the gap between the spray gun and the roller body surface 18, 18' must be set or verified to be correct 54, the spray gun feed rate must be set 56, and the rotational speed of the roller must be set 58 before operation of the arc spray machine is initiated 60. Generally, a spray gun feed rate of 0.2 to 0.5 m/min produces a grit layer thickness of 3 to 10 μm per traverse when the roller body 16, 16' is rotated at 200 to 400 rpm. Preferably, the distance between the spray gun and the roller body surface 18, 18' is set in the range of 150 to 250 mm. After all of the above-discussed parameters have been set, the arc spray machine is energized for a predetermined period of time 62 to deposit a grit layer 22 having the specified surface roughness and specified thickness.

With additional reference to Figure 7, an initial grit layer 22 may be applied 64 to the roller body surface using the arc spray procedure 28, as a "primer" for a subsequent grit layer 22 that is applied by the plasma spray procedure 30. Both an application material and a bonding agent must be selected 66, 68 and then installed or verified to be installed 70 in a feed hopper. During the plasma spray procedure 30, particles of the bonding agent (e.g. titanium oxide) are melted at an extremely high temperature.

The melted boding agent particles and grit particles composed of the application material are then sprayed on the roller body surface 18, 18'. Since the grit particles are not melted, the roughness and thickness of the grit layer is very much determined by grit particle size, not so much by the output power and feeding speed. Simply put, the bigger the particle size, the greater the roughness and thickness.

Similar to the arc spray procedure 28, the operator must set the output power 72, set an arc gas/carrier gas pressure 74, set the spray gun feed rate 76, set the roller rotational speed 78, and verify 80 the distance of the gap between the roller body surface 18, 18' and the spray gun. Generally, a spray gun feed rate of 0.2 to 0.5 m/min produces a grit layer thickness of 3 to 10 μm per traverse when the roller body 16, 16' is rotated at 200 to 400 rpm. Preferably, the distance between the spray gun and the roller body surface 18, 18' is set in the range of 70 to 120 mm. Preferably, the plasma spray machine power is in the range of 40 to 80 volts and 500 to 650 amps, the arc gas pressure is in the range of 60 to 180 psi and the carrier gas pressure is in the range of 30 to 80 psi. The application material/boding agent feed rate is preferably set to 20 to 30 g/min. After all of the above-discussed parameters have been set, the plasma spray machine is energized 82 for a predetermined period of time 84 to deposit a grit layer 22 having the specified surface roughness and specified thickness.

Generally, after the arc spray procedure 28 or the plasma spray procedure 30 has been completed 86, the masking is removed 92. A statistically representative sample of the rollers 10, 10' is inspected 88. Such inspection 88 generally includes measurement of the diameter and run out of the roller body 16, 16' by laser micrometer. The roughness of the roller body surface 18, 18' is measured with a roughness tester and the coefficient of friction of the roller body surface 18, 18' is measured. Finally

a visual inspection is conducted and the finished product is shipped 90 by conventional means.

It should be appreciated that the plasma spray procedure 30 is more expensive to perform than the arc spray procedure 28 and the grit layer 22 produced by the arc spray procedure 28 is more than adequate for use in modern printers. Table 1 provides a comparison of a thermal spray grit roller 10, 10′ in accordance with the invention with several conventional rollers intended for use in printers.

While preferred embodiments have been shown and described, various modifications and substitutions may be made thereto without departing from the spirit and scope of the invention. Accordingly, it is to be understood that the present invention has been described by way of illustration and not limitation.

TABLE 1

	EPDM Rollers	Grit Rollers (aluminum & adhesive)	Grit Roller (Inorganic Particles w/ binder) JP 2,512,332	Grit Roller (Arc Spray)
Manufacturing Process	Either molded or extruded EPDM cut in length, then mounted on shafts	Apply adhesive on shafts, add grit particles, then spray coat another layer of adhesive (could be epoxy, PU or any other bonding agents) to hold particles in place.	Use melamine resin, phenol, polyethylene, or polyamide as binder; mix with inorganic particles via injection process to mold in shape. Shot blast the surface to expose inorganic particle on surface.	Using arc spray technology to coat SUS316 or any other conductive materials on shafts to achieve the desire grit surface
Manufacturing Costs	Very expensive if it is molded. Cutting costs or cutting process could be expensive & tedious if it is extruded EPDM; especially when the specs for perpendicularity and length tolerance is tight.	Total of 3 layers in the coating process. Costly because staging (curing) is required ideally for each process	Tooling up for molds could be really expensive especially when we do high volume production. Leadtime for hard tooling is another issue as well.	One of the least expensive method is done correctly. Also very flexible because there is not hard tooling. Start up time very short too.
Heat Resistance of Coating	Maximum temperature is 100°C or below	Around 100°C or less	Around 100°C or less	The highest of all four, over 800°C
Wear Resistance of Coating	Moderate	Moderate, grit particles could fall off easily even if it is bonded correctly.	High	Very High
Corrosion Resistance of Coating	Very High	High	Very High	Very High
Tensile Bond Strength of Coating	N/A	Lowest of all four	Moderate	Highest of all three, at 6,735 psi
Compression Set of Coating	Could be severe depending on the hardness (shore) of EPDM cots	Very minimum	Very minimum	Lowest of all four. Practically zero simply because SUS316 is rock hard metal
Conductivity of Coating	Not Conductive, extremely bad. Paper dust accumulation could occur; eventually reduce the traction on rollers	Not Conductive. Paper dust accumulation could occur, which reduces the friction & traction of rollers.	Not conductive unless conductive particle is added in binder, but this could be costly if so.	Highly conductive, merely 0.46 Ohm. All static will be grounded to eliminate paper dust formation or accumulation. This will ensure high traction on rollers at all times.
Roughness Control in Manufacturing	Moderate	Difficult to control due to the nature of manufacturing process. Grit particles could stack on one another.	Moderate	Repeatability is very high. Roughness range can be kept at around Ra 3 to Ra 10, depending how the spray machine is set up.
Thickness Control in Manufacturing	Moderate. Minimum thickness tolerance is around +/-0.03mm	Difficult to control due to the nature of manufacturing process. Grit particles could stack on one another.	Moderate, may be around +/-0.03mm	Repeatability is very high. Minimum thickness tolerance can be kept at +/-0.01mm
RoHS Requirement	No hazardous material in EPDM	Contains lead, not allowed in most European countries.	Contains lead, not allowed in most European countries.	No hazardous material in SUS316